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Global Precipitation Measurement

- GPM Science for Industry
- Eric Smith; NASA/Goddard Space Flight Center
- May - 2001

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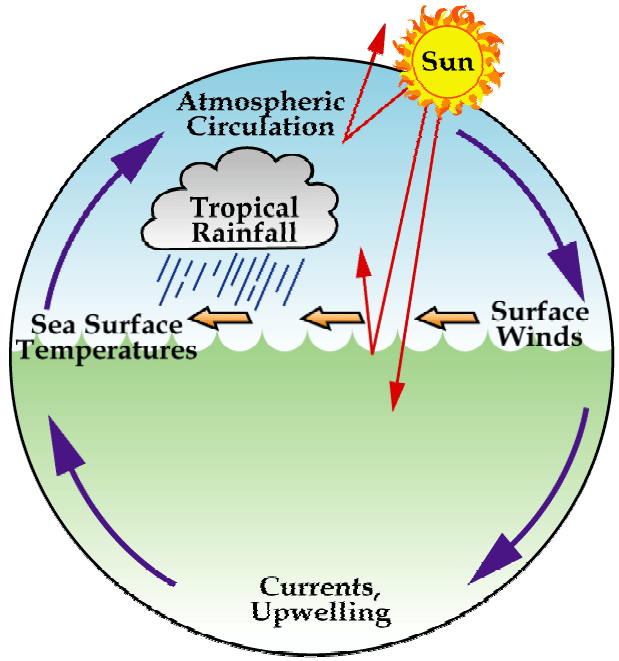
GPM's Key Science Theme

Global Water & Energy Cycle

- **GOAL**: **Observe, understand, & model Earth system to learn how it is changing, & consequences for life on Earth.**
- **SOLUTION**: **Establish existence (or absence) of trend in rate of global water cycle -- acceleration would lead to faster evaporation, increased global average precipitation, & general increase in extremes, particularly droughts & floods.**

GPM will extend TRMM's observations of rainfall rates to higher latitudes thus yielding more complete and accurate representation of global water cycle.

Advanced rainfall measurement core satellite will make detailed & accurate estimates of precipitation structure & microphysical properties -- while constellation of drone satellites flying passive microwave radiometers will provide required temporal sampling of highly variable precipitation systems.



Uncertainty in global tropical rainfall estimates has been reduced from 50% to 25% using TRMM data

Global Water Budget & Water Cycle

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General Equation

$$S = P - E - DIV - RO$$

Oceanic Water Budget

total water tendency (vapor or cloud water)	3D vapor or cloud water divergence	evaporation sublimation	condensation deposition	vertical divergence of vertical eddy transport of vapor or cloud water
$\check{Z}\overline{q_v(p)}/\check{Z}t$	$= -\nabla\bullet\overline{\vec{V}(p)\,q_v(p)} - \check{Z}\overline{\omega\,q_v(p)}/\check{Z}p$	$+ \overline{e(p)}$	$- \overline{c(p)}$	$- \check{Z}\overline{[q_v(p)']\,\omega(p)'}/\check{Z}p$
$\check{Z}\overline{q_w(p)}/\check{Z}t$	$= -\nabla\bullet\overline{\vec{V}(p)\,q_c(p)} - \check{Z}\overline{\omega_c\,q_c(p)}/\check{Z}p$	$- \overline{e(p)}$	$+ \overline{c(p)}$	$- \check{Z}\overline{[q_v(p)']\,\omega_c(p)'}/\check{Z}p$

↓ VERTICALLY INTEGRATE ↓

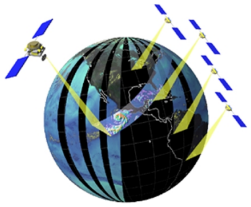
$$\overline{W_t} = - \overline{\vec{U}\bullet\nabla W} - \overline{\vec{U}\bullet\nabla W_c} + \overline{E} - \overline{P}$$

column vapor & cloud water storage	vapor advection	cloud water advection	evaporation	precipitation

Continental Water Budget -- Not Same Problem

$$\overline{S} = - \overline{\vec{U}\bullet\nabla q_l} - RO - BF + \overline{P} - \overline{E}$$

soil moisture/ surface water/ surface snow/ice storage	interflow (water advection) [bulldozers] [dump trucks] [nuclear bombs] [continental drift]	surface runoff & base flow & recharge	precipitation deposition tree leaf-needle drip canopy snow blowoff	evaporation [ground/leaf/snow] transpiration or ET sublimation



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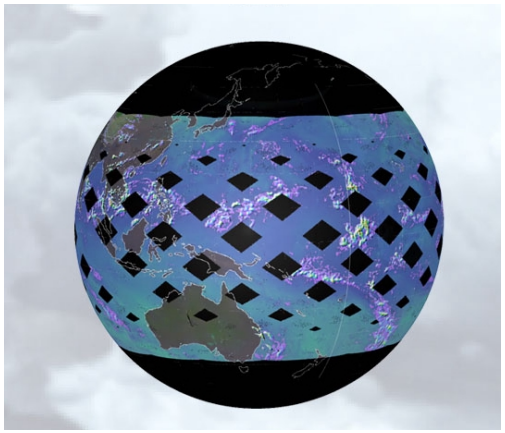
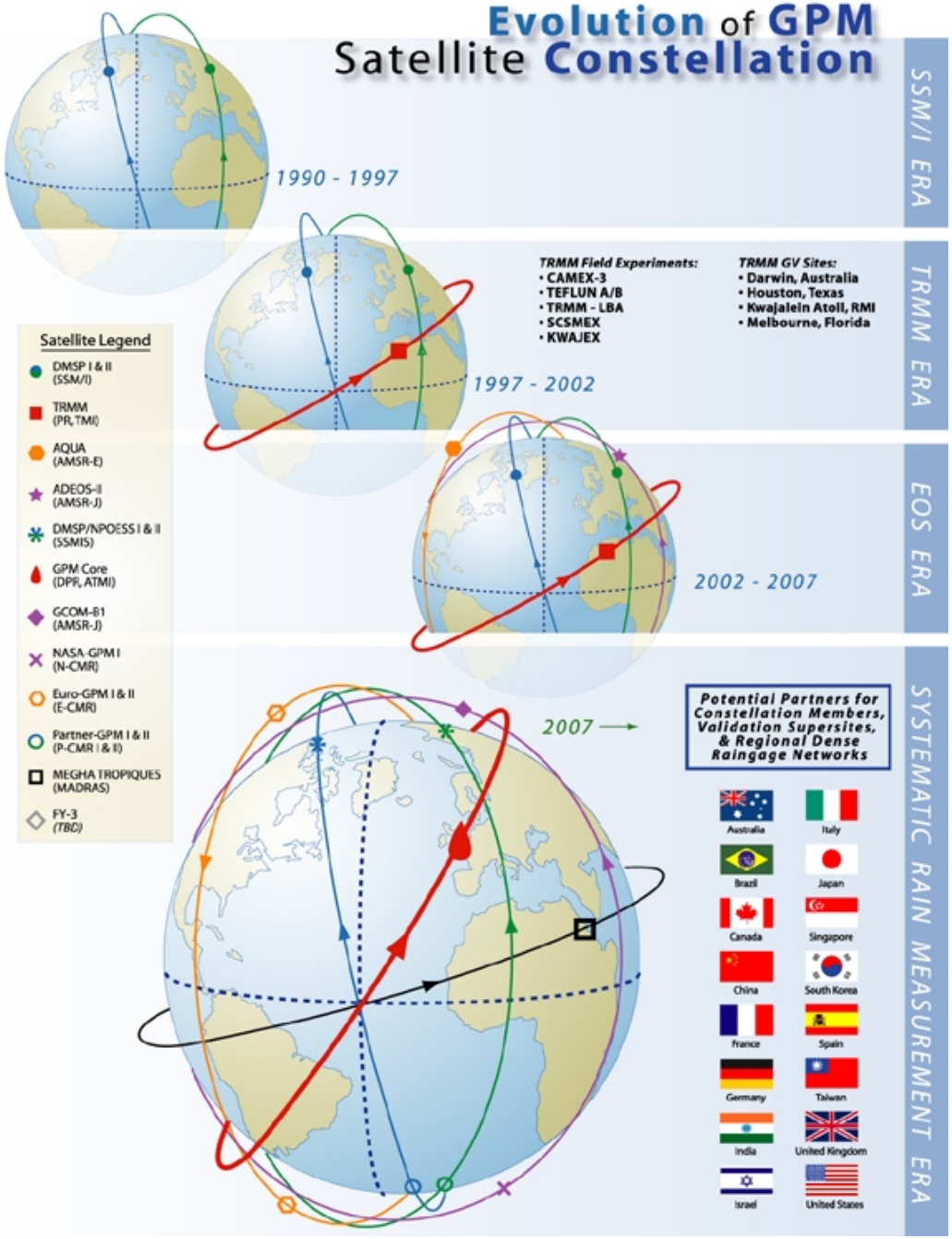
TRMM 1-day coverage





GPM Reference Concept

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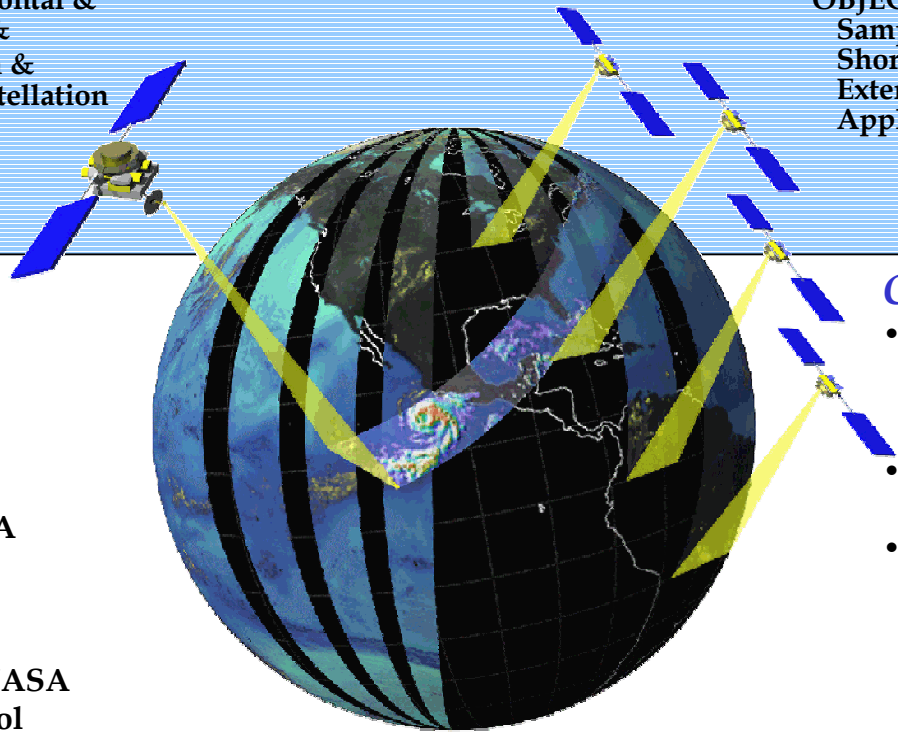
OBJECTIVE: Understand Horizontal & Vertical Structure of Rainfall & Its Microphysical Nature. Train & Calibrate Algorithms for Constellation Radiometers.

OBJECTIVE: Provide Sufficient Sampling to Reduce Uncertainty in Short-term Rainfall Accumulations. Extend Scientific and Societal Applications.



Core Satellite

- TRMM-Like S/C, NASA
- H2A Launch, NASDA
- Non-Sun Synchronous Orbit
  - ~ 65° Inclination
  - ~450 km Altitude
- Dual Frequency Radar, NASDA
  - Ku & Ka Bands
  - ~ 4 km Horizontal Resolution
  - ~250 m Vertical Resolution
- Multifrequency Radiometer, NASA
  - 10.7, 19, 22, 37, 85 GHz V&H Pol

Constellation Satellites

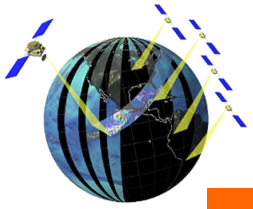
- Dedicated Small or Pre-existing Experimental & Operational Satellites with PMW Radiometers
- Revisit Time
  - 3-Hour goal
- Sun-Synchronous Polar Orbits
  - ~600 km Altitude

Precipitation Validation Sites

- Selected & Globally Distributed Ground- Based Supersites (polarimetric radar, radiometer, raingages, & disdrometers) & Dense Regional Raingage Networks

Global Precipitation Processing Center

- Produces Global Precipitation Data Product Streams Defined by GPM Partners



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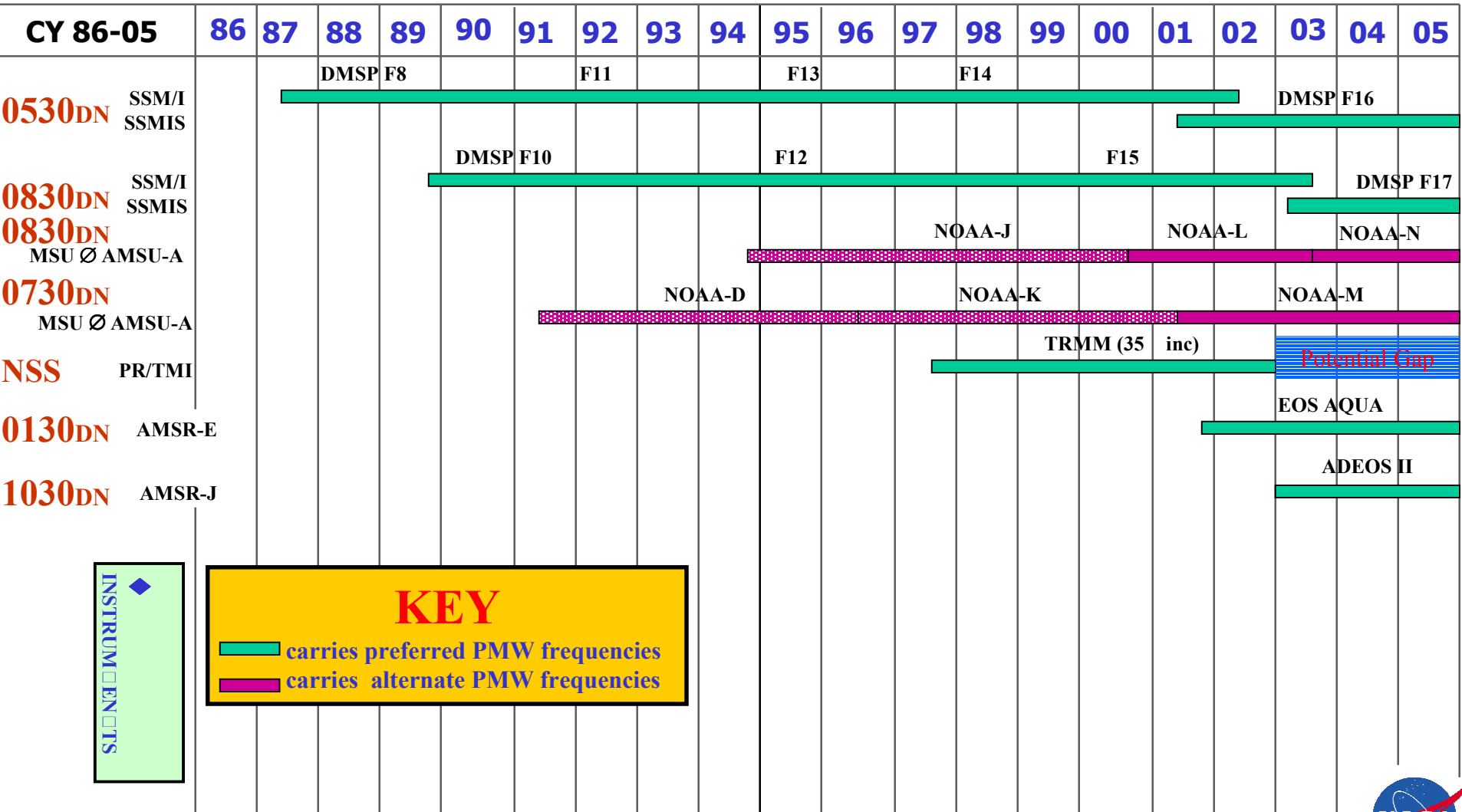
Near Term Satellite Data Streams for TRMM/EOS Eras

from Passive Microwave Radiometers & Precipitation Radars

[at left are actual (bold) nodal crossing times (DN) or non-sun-synch labels]

♦ Continuous Geosynchronous Satellite Coverage by GOES E/W, METEOSAT, & GMS ∅



Projected Satellite Data Streams for GPM Era
from Passive Microwave Radiometers & Precipitation Radars

[at left are either actual (bold) or orthodox (paren) nodal crossing times (DN or AN) or non-sun-synch labels]

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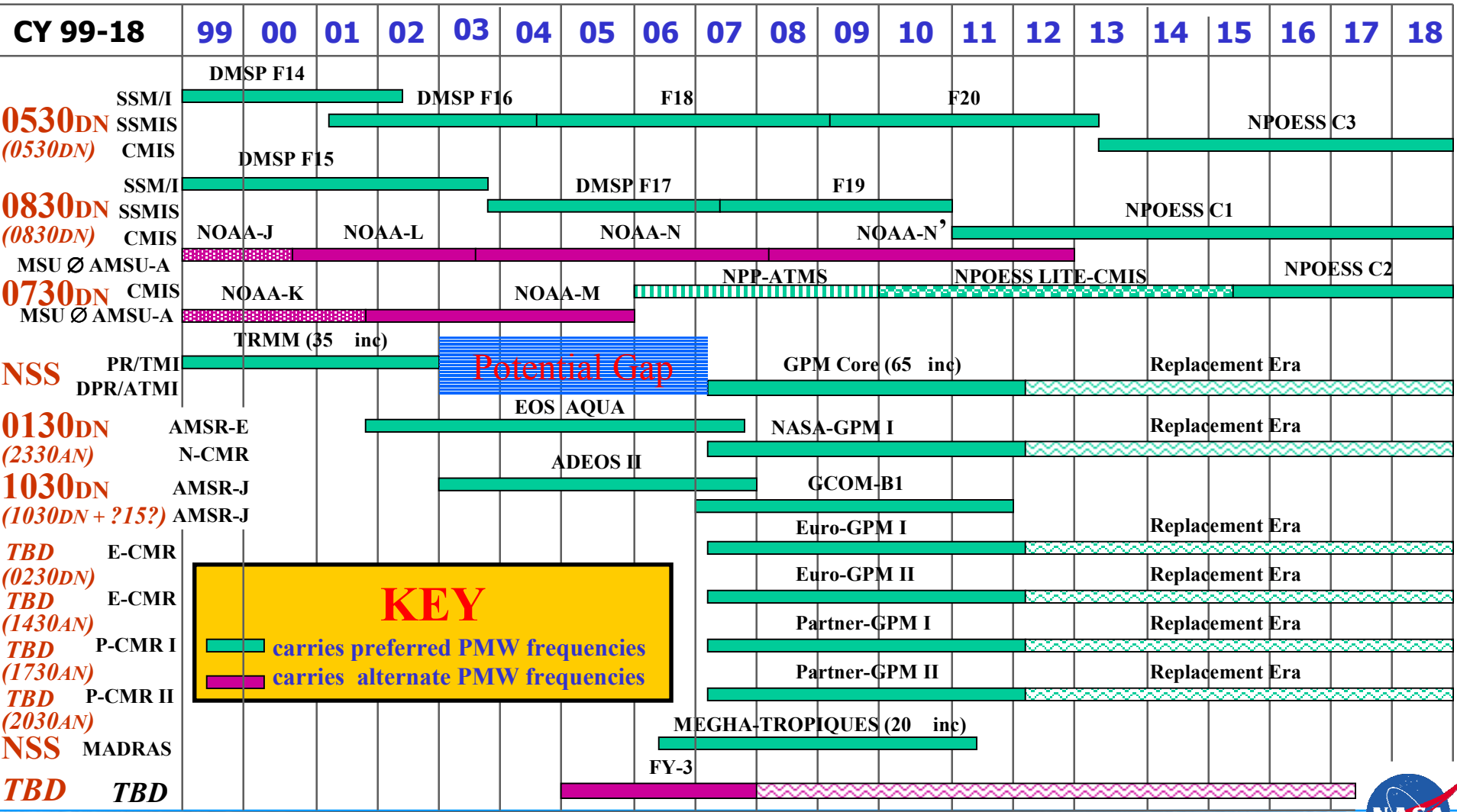
♦ Continuous Geosynchronous Satellite Coverage by GOES E/W, METEOSAT/MSG, & GMS ∅



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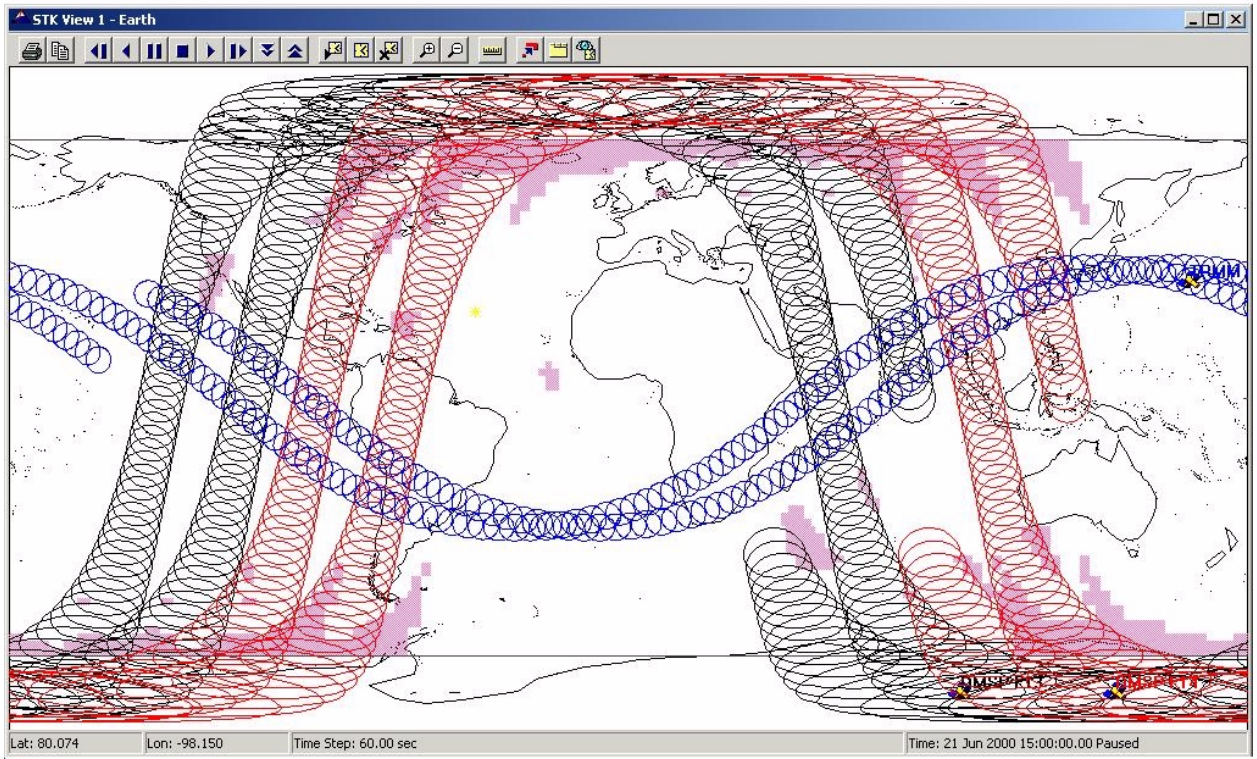
TRMM Era Constellation Coverage



3-hour sensor ground trace

TRMM + DMSP(F14) + DMSP(F15)

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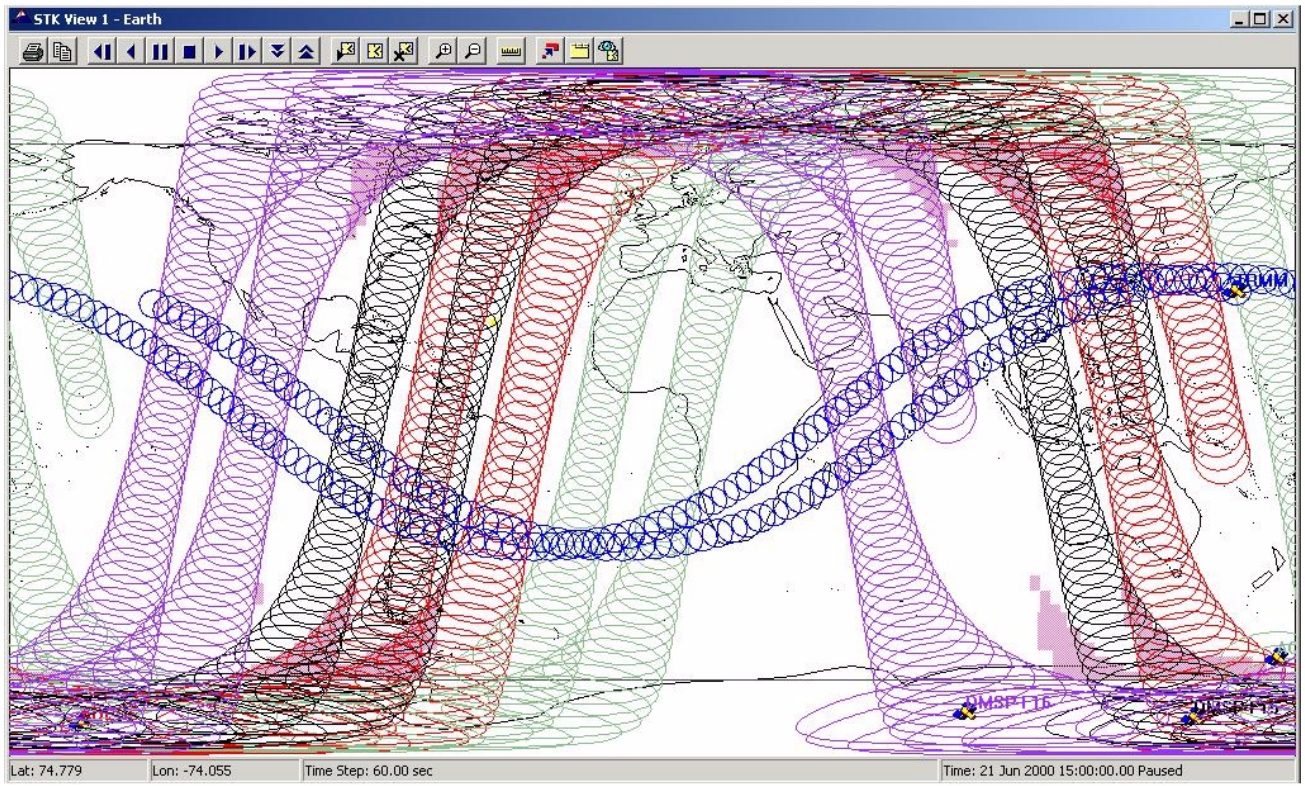
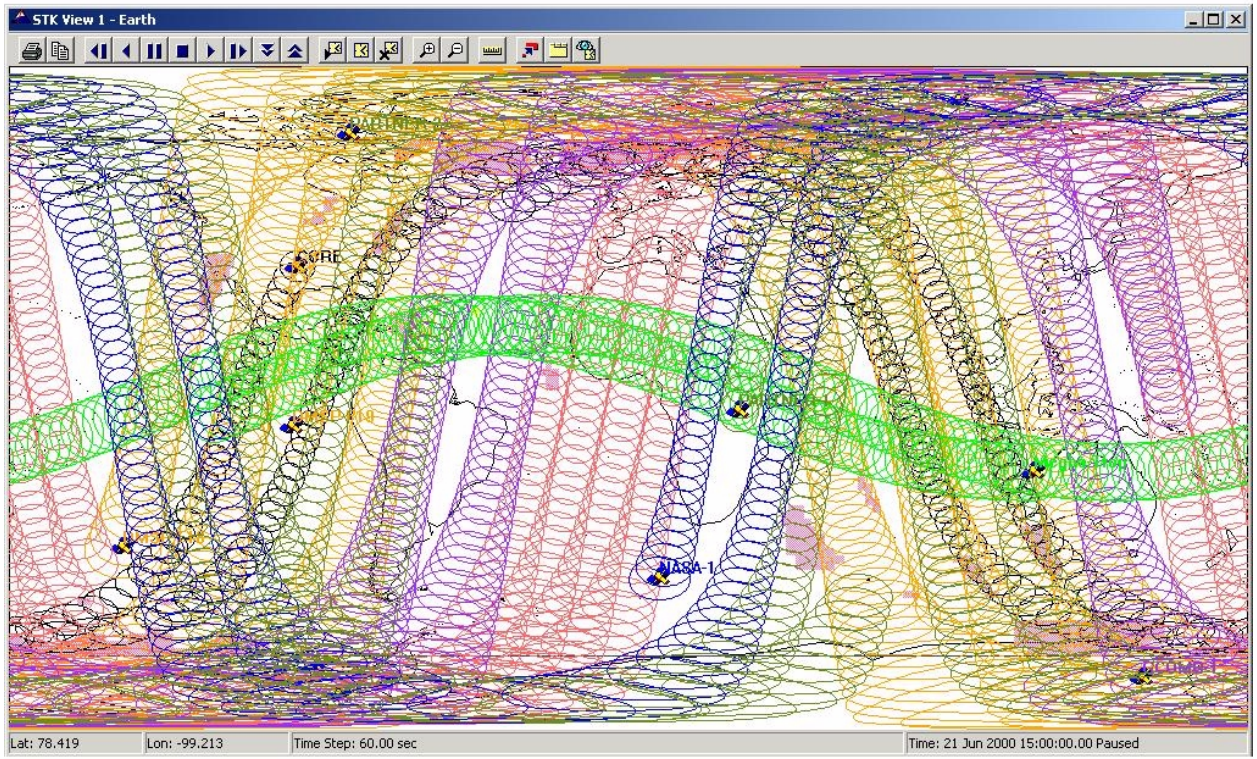
EOS Era Constellation Coverage



3-hour sensor ground trace

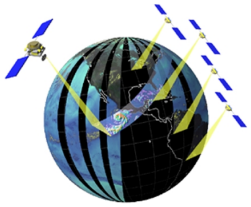
TRMM + DMSP(F15) + DMSP(F16) + AQUA + ADEOS II

GPM Systematic Measurement Coverage
(Core + 6 constellation members)



3-hour sensor ground trace

GPM Core + MEGHA-TROP + DMSP(F18) + DMSP(F19) + GCOM-B1 + NASA-GPM I + Euro-GPM I & II + Partner-GPM I & II



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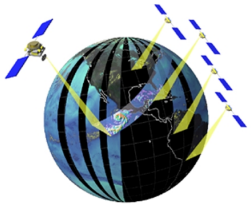
Why Measure Rain ?

Why Study & Try to Understand Global Water Cycle ?

- **Rain is True Global Variable**
  [i.e., its variability is anisotropic and heterogeneous]
- **Rain is 1 of 3 Foremost Weather Prediction Variables**
  [along with temperature & wind]
- **Rain Causes Floods**
- **Rain is Major Climate Change Variable**
- **Rain through Latent Heating is Principle Determinant of General Circulation**
- **Rain is Key Forcing Variable for Eco-Hydrometeorological Modeling**
- **Rain is 1 of 3 Primary Controls on Air-Sea Moisture Fluxes**
  [along with ΔT & surface wind]
- **Rain is By-Product of Microphysical Processes -- Perhaps Least Understood Physics Component of Modern Cloud-Weather-Climate Prediction Models**
- **Rain Manifests Itself within Differing Macrophysical Cloud Systems (connective, stratiform, frontal, orographic &/or warm) whose Spatial-Temporal Distributions are Poorly Understood**
- **Rain Affects Most Everyone's Life & Work -- GPM Offers Possibility that Everyone can Obtain Precipitation Data using Internet-like Access Facilities**



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Why GPM ?

past success ? ply users with rain data ? recycle our skills ?

[maybe 3 %]

Improved Measurements

Global Coverage (includes snow-ice zones)

Frequent Sampling (no worse than 3 hourly -- critical for hydromet)

Direct Detection of Microphysical Properties & Processes

[water-ice; LWC/IWC; suspended-precipitating; r_{eff}; v_{eff}]

4D Latent Heating

Morphological Classification

[convective, stratiform, frontal band, orographic &/or warm]

Improved Physical Modeling

Microphysical Process Models (via better microphysics & precip obs)

Cloud-Mesoscale Models (via better microphysics & precip obs)

NWP Models (via better data assimilation of latent heating)

Land Surface Process Models (i.e., eco-hydrometeorological models)

Ocean Salinity-Fresh Water Lens Models

Snow-Ice Accumulation Models

Model Simulations of Climate State & Climate Change

Application Models

[severe storms (hurricanes, flash floods, electrified tornadic storms); flood hazards; agriculture; transportation & communication; construction; recreation; ships at sea; energy]

Improved Technology

Advanced Multi-Frequency/Polarization, Doppler Radars

Advanced Sat Constellation & Sensor Scanning Strategies

Advanced-Large Real & Synthetic Aperture MW Antennas

Promote Complimentary Hydrological Measurements

Supersite Template

Focused Field Campaigns

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GPM Core Satellite
Radar/Radiometer
Prototype Instruments

Piloted

UAVs

Meteorology-Microphysics
Aircraft

150 km

Legend

- Data Acquisition-Analysis Facility
- Polarametric Radar
- Uplooking Radiometer/Radar
- Meteorological Tower
- Site Scientist (3)
- Technician (3)

DELIVERY

- Retrieval Error Synthesis
- Algorithm Improvement Guidance
- Validation Research

5 km

150 km

100-Site Hi-Res Domain
Center-Displaced with Uplooking
Radiometer/Radar System
[10.7,19,22,35,85,157 GHz/14,35,95 GHz]

100-Site Lo-Res Domain
Centered on Pol-Radar

Triple Gage Site
(3 economy scientific gages)

Single Disdrometer/
Triple Gage Site
(1 high quality-Large Aperature/
2 economy scientific gages)

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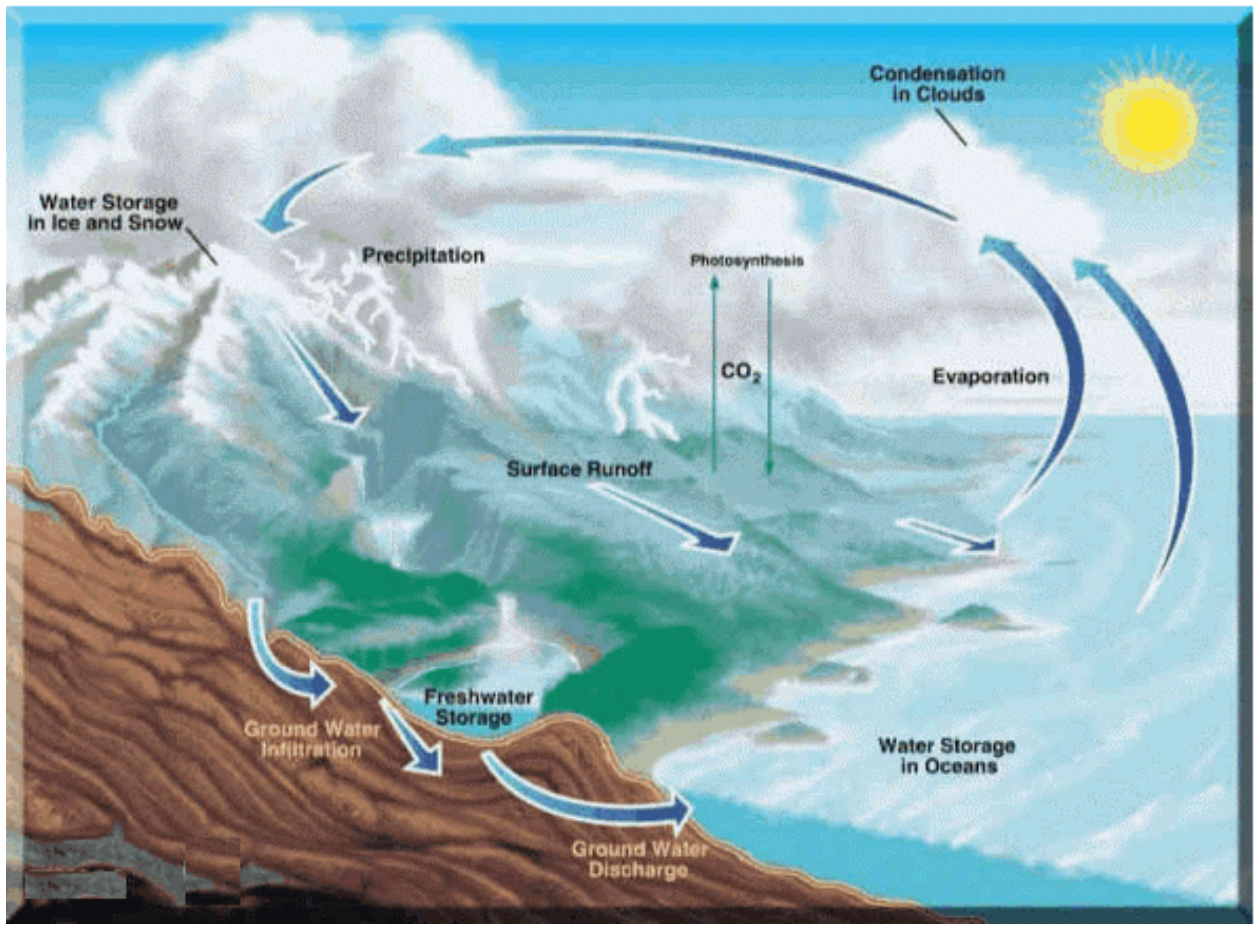
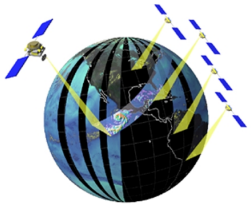
A Global Satellite Precipitation Observing System Would Be Optimized with Additional Global Measurements Central to Understanding & Predicting Global Water Cycle





Global Precipitation Mission (GPM) Purpose

1. Measure Rainfall Accurately, Globally, & Often
2. Stimulate GWC Research Across Scale Spectrum
3. Underwrite Compelling Rainfall-Based Applications
4. Improve Space Technology for Rainfall & Synergistic Measurements
5. Deliver Effective Education/Media/Commercial Outreach Program

Better Rain Measuring	Better Sampling	Better Methodologies
DSD-centric with physical validation	constellation design & GEO data infusion	marriage of measurements & prediction models

Overarching Science & Technology Goals

Technology

- advance multiparameter rain radar instruments
- advance SA/RA rain radiometer instruments
- move toward operational space-based rain measuring system

Research

- understand & quantify GWC dynamics & variability of atmos-bio-cryo-hydrospheres
- seek closure of mass-energy budgets at basin scales
- understand relationships between GWC & climate and underlying predictability

Applications

- improve QPF of landfalling TCs & MLCs
- improve flash flood forecasts of alpine storms
- improve prediction of fresh water resources